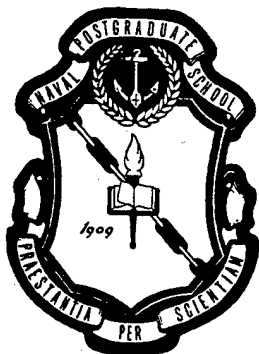NPS-09-96-004

Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1995

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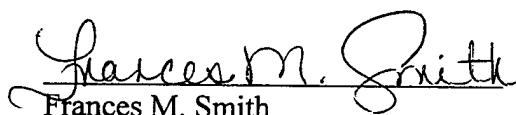# NAVAL POSTGRADUATE SCHOOL
Monterey, California

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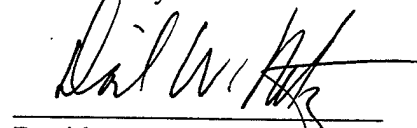
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13. ABSTRACT (Maximum 200 words.)

This report contains 26 summaries of research projects in the Department of Computer Science which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports.

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THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.
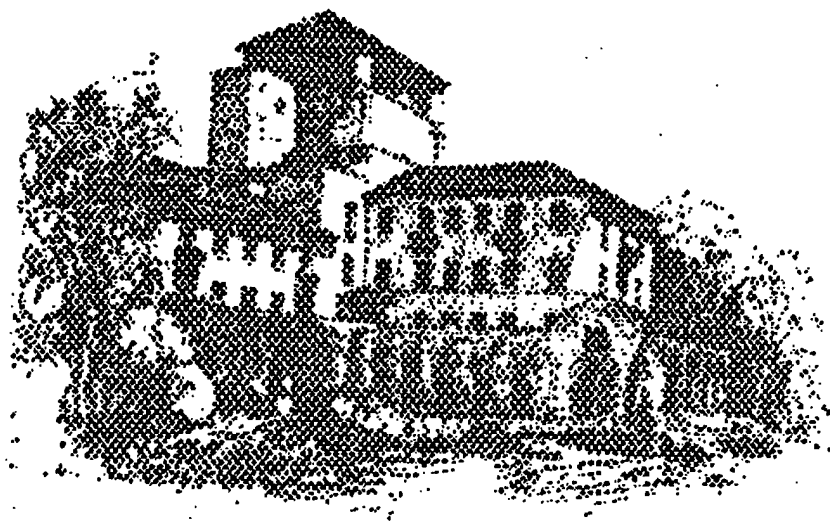
Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.

- Keep faculty on the leading edge of advances in defense-related science, technology, managment and policy to ensure that the latest information is incorporated into NPS courses and curricula.

- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.

- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.

- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.

- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).

- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.

- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Computer Science Department provides graduate-level education and research in fundamental principles of computing and in critical technologies in support of DoD missions: virtual reality, real-time embedded systems software, networking and high-performance computing, military robotics, database systems, and artificial intelligence.

Table of Contents

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COMPUTER SCIENCE

The Computer Science Department has active research in several important areas of interest to DoN. Below is a cross-sectioned description of the major thrusts:

Software Engineering

Prof. Luqi's research is to enable rapid prototyping of hard real-time systems via a Computer-Aided Prototyping System (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly and executed to validate the requirements. The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and real-time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging.

Rapid prototyping is a means for stabilizing and validating the requirements for complex systems by helping customers visualize system behavior prior to detailed implementation, e.g. for embedded control systems with hard real-time constraints. CAPS supports an iterative prototyping process characterized by exploratory design and extensive prototype evolution. This should enable the first production version of the software to match user needs and reduce the need for expensive modifications after delivery. The current version of CAPS has been used to generate a software prototype of a C3I system with hard real-time constraints. The preliminary result of such an approach has shown great promise.

The major objective of Prof. Shing's research is to develop efficient algorithms and tools to support the computer-aided rapid prototyping of real-time embedded systems. The process of design and development of real-time embedded systems is often plagued with uncertainty, ambiguity and inconsistency. The timing requirements are difficult for the user to provide and for the analysts to determine. It is also very difficult to determine whether a delivered system meets its requirements. Rapid prototyping provides a means to alleviate the risks and difficulties in real-time embedded systems.

Specific topics Prof. Shing is investigating include efficient heuristic scheduling algorithms for real-time systems, and incremental attribute-evaluation and software architectures for distributed real-time embedded systems.

Formal methods and associated automated decision aids have a large potential for practical impact that has not been fully realized. To help bring this about, Prof. Berzins has developed a formal specification language specifically designed for large scale applications that include parallel, distributed, and real-time systems. He is currently investigating a variety of methods and tools for partially automating many aspects of software development.

Prof. Berzins seeks to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in development and maintenance of large software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

Prof. Berzins has also investigated change merging for specifications and for software prototypes of real-time systems. He integrated a change merging mechanism for specifications with an inheritance mechanism and investigated both applications and formal properties of the resulting structure. He has been working on an analog of the program slicing method for the PSDL language. PSDL presents new problems because it includes explicit real-time constraints and parallel operations. He has also designed an automated design management and job assignment system. The main

advance provided by this system is automated scheduling and job assignment for teams of engineers in an environment where plans are uncertain, partially known, and subject to change while the work is in progress.

As attempts are made to automate the software development process through rapid prototyping and other means, there is an increasing need for new forms of automated analyses of specifications and code. These analyses can provide useful information about functionality and behavior that can aid in the software design process. The goal of Prof. Volpano's Advanced Type Systems Project at NPS is to develop new forms of static analyses within the well-understood context of type systems.

There are two major research thrusts in the project. One involves developing the type-theoretic foundation for sound polymorphic typing in the popular imperative programming languages C. A sound type system for a polymorphic dialect of K&R C has been developed. It is very well known that getting soundness in the context of polymorphism and pointers, or references, is difficult. The system was proved sound with respect to a natural semantics for core C. The type system of Edinburgh LCF ML was also proved sound. Although widely conjectured to be sound, its soundness actually remained an open problem for almost 20 years.

Prof. Shimeall's interests center around a consistent view of the analysis of software. During the development of software there are a variety of properties that must be applied and validated to the software, including correctness, safety, security, and modifiability. While these properties are very diverse, there are a set of approaches that are shared in the validation of these processes.

Prof. Shimeall's research has identified three basic approaches to the analysis of software with respect to the above properties: similarity, individuality and source-affinity. Tools have been constructed to apply these approaches to software: Similarity: Reacher - reachability condition analyzer; Falter - activation condition annotator; Spacer - propagation condition analyzer; Viewer - user interface to the similarity toolset; Individuality: FTE - fault/event tree graphical editor; FT2PN - fault tree/Petri net converter; PN2FT - Petri net/fault tree converter; ACTT - Ada/fault tree converter; Source-affinity: Tparse/An - variable-initialization analyzer; AAPSLC - Ada physical source line counter. Taken together, these tools provide a flexible framework for addressing the analysis of a variety of software properties, and they have been applied to several systems to examine correctness, safety and modifiability concerns. Work in progress includes extending the functionality of these tools, adding additional tools to automate other analysis phases and applying these tools to security and other software properties.

Computer Graphics and Visualization

The NPSNET Research Group is a group of faculty (headed by Profs. Zyda and Pratt), staff, and students that work in all areas of networked virtual environments. The research group is currently focused on the following virtual environment (VE) research topics: the large-scale networking of virtual environments (environments greater than 1,000 players), VE network applications protocols, rapidly reconfigurable VE network protocols, Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) protocols, the real-time walkthrough of large-scale networked VEs, world modeling software for managing large scale networked VEs, the instrumentation of the human body and its representation in the networked VE, hypermedia integration (how we place video, audio, imagery and textual data in the networked VE), and geometric modeling (terrain, building and other object modeling).

The NPSNET Research Group's efforts focus on the development of the above software areas and the integration of proven components of that work into a core software system, NPSNET. NPSNET is currently capable of simulating articulated humans, and ground, air and sea-going vessels in the DIS networked virtual environment. NPSNET can support about 250-300 players using currently available networking and workstation technology. NPSNET is the first 3D virtual environment that is capable of playing across the multicast backbone (MBONE) of the Internet.

Real-time (3D) computer graphics workstations have progressed to a point where they can be used for Out The Window (OTW) visual simulation systems. The key to the development of these systems is the underlying software. As with most

leading edge technologies, the construction of the required software is a black art. As such, the focus of the research has been the development, documentation, and distribution of workstation based OTW visual display systems. A major component of this research is the distribution of the simulation across the network. This allows multiple users to interact with each other in a virtual environment. This is one of the key premises of DIS, inserting humans into the virtual environment where they can "free-play" different scenarios. While this sounds simple, the problems of networks, human/computer interfaces, and data management are significant research topics. While the humans in the virtual environment comprise an integral component of the system, there are not enough manned simulators to sufficiently populate the world.

To provide the additional entities, Prof. Pratt is conducting research in the use of traditional constructive combat models and autonomous agents to populate the world. By providing an interface to the traditional models, we can leverage off the work that has been done before in combat modeling. This, combined with the research on autonomous agents, provides a mechanism to provide friendly and opposing forces to complement the manned simulators.

One of the key components of a military virtual environment is the geometric description of the terrain database. To address the importance of the terrain database, NPSNET has active research projects in the areas of terrain modifications, culling, and polygon reduction. NPS is quickly becoming one of the leading organizations within DoD for the understanding and conversion of terrain database formats.

Research for the development of highly realistic tactical battlefield simulation systems by Prof. Baer is organized around three main areas. These are: (1) development of algorithms for visualizing realistic battlefield effects including 1 meter or better terrain backgrounds, photo realistic targets, and environmental effects and battlefield; obscurants (2) development of database generation and update systems designed to reduce instrumentation, photographic, and video data to object-descriptor data bases; and (3) development of high speed low cost parallel-processor technologies in order to execute the algorithms and systems resulting from the two previous research areas.

Artificial Intelligence (AI) and Robotics

The major objective of Prof. Kanayama's research is to investigate fundamental theories in autonomous mobile robotics. Since autonomous self-contained robots have complete freedom in motion, the topic is fundamentally interesting in robotics and AI. Furthermore, there are tremendous opportunities for such robots to perform practical tasks in the real world. Prof. Kanayama tests and evaluates theories on the Autonomous Indoor Mobile Robot Yamabico-11. Research activities cover abstract mathematical models, intelligent algorithm finding, software development, and hardware construction. Specific topics Prof. Kanayama has been investigating include: a smooth vehicle tracking algorithm, sonar interpretation, rigid body motion planning, automated cartography, vehicle control by a steering function, a high-level mobile robot language MML, a real-time hardware/software architecture for mobile robots, motion planning for an autonomous underwater vehicle, and fast gait planning for an underwater walking robot.

The role of robotics in manufacturing is already well established and is an important factor in increasing industrial productivity. In contrast, the introduction of robots into military operations has just begun. This is due in part to justifiable concerns about removing human control from potentially lethal systems, but perhaps to a greater extent is the result of the relatively weak capabilities of mobile robots operating in the unstructured or even hostile environments typical of military situations. Prof. McGhee's research is concerned with adapting existing robot technology to suit military applications, and with making theoretical and engineering advances in areas where current knowledge is inadequate for a selected application. He pursues this goal both through the construction of prototype systems for concept demonstration, and by means of real-time graphical dynamic simulation studies in support of such research.

With the recent rapid increase in interest in networked interactive simulations as an alternative to actual field exercises, the accurate modeling of vehicle dynamics needed for mobile robot design studies has taken on a new and larger urgency. At present, Prof. McGhee's research is centered around the application of unmanned submersibles to mine countermeasures. Both swimming vehicles and walking vehicles are being considered for this purpose. In the first

instance, the NPS Autonomous Underwater Vehicle (AUV) is available for experimental studies. In the second, various vehicles derived from his earlier research on terrestrial walking machines are being considered. Accurate simulation models are being used in both cases to permit not only concept evaluation, but also the development of real-time control software through "hardware in the loop" simulation studies.

The MARIE project of Prof. Rowe seeks to build an information-retrieval system for large multimedia databases that exploits the contents of the multimedia. This requires image processing, but especially natural-language processing since descriptive captions are often associated with valuable multimedia data and are much faster to analyze than images. MARIE exploits a large technical lexicon and a trainable statistical parser using statistics on word senses, syntactically-grouped word-sense pairs, parse rules, and rhetorical heuristics. MARIE's image processing uses robust natural-image segmentation methods, together with a neural network for classifying regions; the network also exploits linguistic reference information. MARIE also addresses system-building issues for large multimedia databases by considering the problem as one of efficient information filtering of desired data. Prof. Rowe has developed mathematical criteria for optimal such information filtering, including data-parallel implementations.

The METUTOR project of Prof. Rowe helps teachers write and run tutors for tasks involving sequences of actions. With METUTOR, tutors are considerably easier to build than with conventional frame-based tools, while at the same time being smarter in analyzing student behavior. METUTOR tutors use planning methods of artificial intelligence to figure out what a student is trying to do, which gives powerful inference capabilities for finding student errors, categorizing them, and tutoring them. METUTOR permits mapping of domain concepts to graphical elements, which are then combined into a visual display of domain state.

Prof. Rowe also conducts research in construction of universal (all-situations) plans for robots moving in natural domains. These are like potential fields but better: They give the provably best thing to do in any situation.

Parallel, Distributed, and Network Computing

Designers of high performance computing systems are increasingly turning to parallel processor systems to achieve high speed at relatively low cost. In such a system, processing elements are duplicated (numbering in the hundreds or thousands) and often the memory is distributed to support parallelism. While the hardware has been rapidly improving, the software for such machines is still archaic. There is no agreement on how to program these machines, nor on the best way to design a parallel programming language, compiler, operating system, or application program. Thus, the central focus of Prof. Lewis' research has been in the design and development of parallel programming environments which support architecture-independent parallel programming.

Recently, in a joint research project between NPS and the Russian Academy of Sciences Systems Programming Institute in Moscow, Russia, Prof. Lewis is designing and implementing a parallel programming environment called mpC. This is a language, translator, and scheduling system for automatically mapping a parallel program written in mpC onto an arbitrary parallel computer. The network features of mpC permit rather general expression of the solution to a problem in terms convenient to the programmer. But this may be non-optimal use of the parallel hardware. Therefore, scheduling tools are needed to optimize the performance on a specific machine.

The hardware necessary to create a meta-computer has existed for twenty years. Likewise, heterogeneous programs-consisting of multiple parts, each running in a predefined sequence and on potentially different machines-have been around since the Sixties; these programs have been very latency-tolerant, meaning that the results from one part of a program often had to be written to tape and hand carried to another computer where the next part would execute. The demands of today's environments, particularly that of the military world, can no longer tolerate these latencies. In a crisis situation, where data acquisition, transfer, computation, and display must happen within minutes to be of any use, traditional methods have become outdated and, indeed, dangerous. At a basic level, a meta-computer is a distributed and heterogeneous collection of computers networked together, all coordinated by one or more master schedulers. Such a meta-computer can potentially, and in a matter of minutes, process a request from a hot spot, acquire

the data from satellite, compute in a secure facility in the US, and present the results to the field commander somewhere in the Middle East. In addition, the meta-computer might be processing hundreds of such requests simultaneously.

Prof. Kidd and Prof. Hensgen's research generally involves the architectural design of such a meta-computer. To this end, he has created the Heterogeneous Processing Testbed (HPT) in the Heterogeneous Processing Laboratory (HPL). The HPL supports research in meta-computing and heterogeneous processing by providing a fully controlled environment for testing, development and evaluation.

In a distributed and heterogeneous environment, two of the biggest issues are where and when to schedule jobs. Though seemingly settled for "single box" architectures, it is far from solved in a distributed environment, especially one which combines many "boxes" of highly varying architectures. Some of the issues Prof. Kidd and Prof. Hensgen's research attempts to address are: (1) what optimization criteria should we use; (2) how do you schedule jobs to meet various constraints on when and where they are to execute, such as job A must execute in parallel with job B and before job C; (3) how do you avoid resource contention related to the sharing of resources, such as disks, CPUs and networks, by different jobs; and (4) how do you meet the optimization criteria.

One ingrained assumption underlying Computer Science is determinism. Though never completely true, it has been "good enough" in traditional architectures. As the development of distributed computer evolves, determinism is no longer a valid assumption/simplification. Uncertainties derived from various sources, such as network traffic, shared disk use, and cache use, make job runtimes and other time related events better represented by a probability distribution. To this end, Prof. Kidd and Prof. Hensgen's research applies probabilistic and statistical techniques in scheduling and learning.

Prof. Lundy's research interests are in telecommunications networks and computer networks generally. Most of this work has been in the specification, analysis and testing of communications protocols. This often leads him to suggestions for possible improvements of existing protocols, correcting errors in them, or both. Recent work is in high speed transport protocols, multicasting protocols for reliable communications, and wireless protocols. Prof. Lundy is also interested in military communications and in network security. In the past year, Prof. Lundy has been studying and evaluating some of the US Army's current networks and their future plans for these networks.

Computer Security

As the value of the assets stored in computer systems increases, attacks by highly motivated, technically capable opponents using malicious software and subversive techniques become more likely. A scientific foundation exists which may be employed to build secure computer systems and certified software to protect sensitive information. Several areas of research are being pursued.

The widespread use of commercial off-the-shelf (COTS) platforms enforcing security policies with a high level of assurance has been hampered by a lack of compatibility with existing COTS and government-off-the-shelf applications software. Trusted file system research is intended to permit the use of both high assurance security policy-enforcing platforms and the massive body of application software currently available. Prof. Irvine's government-industry team plans to build a prototype system providing high assurance controlled sharing of information while allowing users to continue to run their favorite COTS workstation applications. An extension to the initial effort would be the development of a high assurance messaging capability permitting the selection of cryptographic keys and methods based on information security levels.

Without careful analysis, execution of application software can sometimes result in the corruption or exfiltration of sensitive information. Profs. Irvine and Volpano are developing a type system in which it is possible to prove that code is secure. The objective of this research is to construct a tool to detect places where either legacy or new software is leaking information. Standard type inference techniques will be used in the implementation so that, within a typical software development tool such as an editor, users will be informed automatically regarding the security properties of

their programs. This could be useful in the context of Web programming where perhaps a downloaded script attempts to make some sensitive information about the user, say a mail folder, publicly available by mailing it to everyone. Such unauthorized disclosures would be prevented if the script were type checked in a system prior to execution.

The use of covert techniques to export sensitive information from trusted systems is also being explored by Prof. Irvine. This research will include the analysis of encoding techniques for exploitive purposes as well as empirical studies of the efficacy of these covert techniques

Databases

Prof. Wu's main research interest is in creating a unified database front-end system that provides easy-to-use yet powerful common language to access varying types of relational data management system (RDBMS), and shields the complexity of underlying RDBMS. His system called GLAD II (Graphics Language for Accessing Database) allows users to interact with different relational DBMS by providing a common graphic language called DFQL (Data Flow Query Language) that is based on a data flow diagram. The system automatically translates a user specified DFQL query into the equivalent query statements recognized by the connected backend DBMS. At present, the prototype connects to Oracle and translates the DFQL queries into the Oracle's SQL statements.

Prof. Wu's work is different from other similar-looking work and commercial products in that theirs only support a SQL connectivity, i.e. theirs do not shield users from the complexity of SQL. In contrast, DFQL provides a more logical, higher-level, and consistent query language. Users of DFQL do not have to bother with the poorly designed language features in SQL. In other words, theirs do not eliminate the semantics problem associated with data retrieval. DFQL is a graphic query language based on relational algebra. It has been designed with sufficient expressive power and functionality to allow the user to easily express database queries. DFQL is relationally complete and includes an implementation of aggregate functions. An object-oriented implementation allows programmers to easily create their own DFQL operators from the primitive and other existing user-defined operations. This extensibility of query language is unique, no other query language allows such extensibility. The overall intention is to provide the user with a simple-to-use, yet powerful and extensible tool to implement database queries. A human-factors analysis comparing DFQL and SQL showed DFQL was statistically better than SQL.

COMPUTER SCIENCE

Computer Science Laboratories

The Computer Science Department has computing facilities to support instruction and research in the core areas of computer science. Departmental computing facilities include the Academic Computing Laboratory and laboratories for artificial intelligence and robotics, computer graphics and virtual worlds data base, parallel and distributed systems, computer security, and software engineering.

The major components of the Academic Computing Laboratory are large-capacity Sun and Solbourne servers. These servers are interconnected through Ethernet using TCP/IP protocols to form a departmental backbone network. Attached to the backbone are network connections to local networks of individual laboratories. Communication servers and printer servers are also connected to provide terminal and modem access and printing services across the entire network system. Full Internet and World Wide Web connections permit access to other networks such as MILNET, NFSNET, CSNET and BITNET. Each of the other laboratories are equipped with modern high-performance workstations tailored to their applications. The department has nearly 200 workstations ranging from IRIS ONYX, Indigo, Indigo 2, and Indy graphics workstations; SUN SPARC-Station 2s, 10s, 20s; and SUN 640 MP and IPX to Soilborne Series 5 servers and S4000 computers, HP 700s, and image-processing equipment. The Microcomputer System Laboratory has 64 32-bit transputers and various MacIntosh and PC compatible personal computers

Most computers are equipped with UNIX-based operating systems that support a variety of programming languages such as Ada, Lisp, Prolog, C and C++. Also supported are a wide variety of data base languages, word-processing packages, compiler generators, and networking and communication software. In artificial intelligence, the department supports various knowledge-based and expert development systems, and several prototype military robots. In computer graphics, the department supports a comprehensive real-time graphic library, which provides access to special hardware features and functions for creating and manipulating graphic objects. In software engineering, the department supports a variety of advanced software-development tools including X-window development systems, an object-oriented data base, syntax-directed editors, source-level debugging tools and configuration and version control management software. In computer security, the department supports a laboratory with a variety of trusted systems, ranging from class B1 through class A1. These systems support UNIX-like as well as more primitive operating system interfaces, and they support a wide variety of tools and applications. Several of these systems represent samples of the systems and applications in use within DoD.

9

FY95 REIMBURSABLE PROGRAM
Department of Computer Science

K Dollars

Legend: ☆ FY93 AVAILABLE ✳ FY94 AVAILABLE ✦ FY95 AVAIL
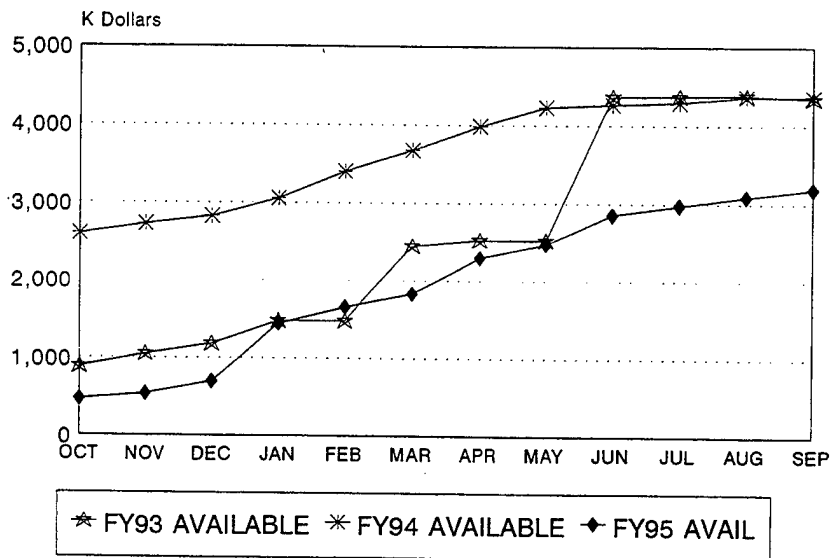
Figure 1. Reimbursable Funds Available by Fiscal Year.
This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities

DEFENSE 37%
OTHER 1%
NSF 8%
NAVY 20%
ARMY 34%

Figure 2. FY95 Reimbursable Sponsor Profile.

COMPUTER SCIENCE

REALISTIC BATTLEFIELD SIMULATION
Wolfgang Baer, Research Associate
Department of Computer Science
Sponsors: Test and Experientation Command (TEXCOM), Training and Doctrine Analysis Command (TRADOC), and U.S. Army Missile and Space Intelligence Command (MSIC)

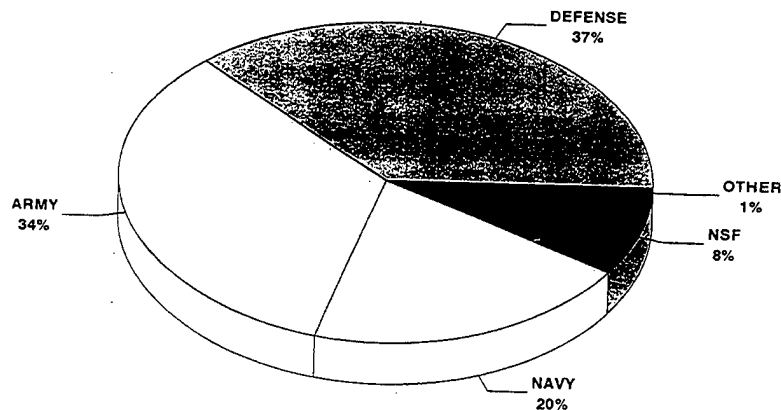**OBJECTIVE:** The research objectives are directed toward the development of highly realistic tactical battlefield simulation systems for weapons test, training, mission rehersal, and analysis applications.

SUMMARY: Research for the development of highly realistic tactical battlefield simulation systems is organized around three main areas. These are: (1) Development of algorithms for visualizing realistic battlefield effects including one meter or better terrain backgrounds, photo realistic targets, and environmental effects and battlefield obscurants, (2) Development of database generation and update systems designed to reduce instrumentation, photographic, and video data to object descriptor data bases, and (3) Development of high speed low cost parallel processor technologies in order to execute the algorithms and systems resulting from the two previous areas.

During FY '96 specific research activities included the development of a SGI X-windows based perspective view generator software which included the capability to display a hierarchical terrain database structure from resolutions of 9mm to 64km elements allowing seamless worldwide operation with views from one meter to 40 million meters above the ground.

In parallel to the development of the perspective view generator a global instrumentation oriented database design was developed and an initialization and data creation toolbox developed which allowed standard data sources (DTED and SPOT) to be integrated with high resolution aerial photographs. A database for California was developed and a simulated flight between Fort Hunter Liggett and China Lake conducted.

A substantial effort during this year included the integration of cloud model outputs from Army research Lab CLOUDSIM and WAVES models to allow metrically accurate sky cloud and ground shadow effects over video realistic terrain.

In the area of parallel processing integration, maintenance and repair of a 21 processor transputer based PowerPC system which allows 16 FPS of video realistic battlefield imagery to be generated under operator flight stick control continued. A procurement effort and benchmark tests of Pentium based machines under the Linux operating system was conducted in order to determine the feasibility of using low cost commercial components to host high speed simulations. This research looks very promising.

PUBLICATION:

Baer, W. and Reed, C., "Global Terrain Database Design for Realistic Imaging Sensor Simulation," Contract # RVD4R Defense Intelligence Agency Missile and Space Intelligence Center, Redstone Arsenal, AL, 1995.

CONFERENCE PRESENTATIONS:

Baer, W., "Global Terrain Database Design for Realistic Imaging Sensor Simulation" Thirteenth DIS Workshop on Standards for the Interoperability of Distributed Simulations, Vol. 1, pp. 19, Orlando, FL, 18-22 September 1995.

Baer, W., "Parallel Processing Visualization of Environmental Effects on High Resolution Terrain," ITEA Modeling and Simulation Workshop, Paper electronically Published through WSMR's web site at address: http:HI55.148.13.188/wsmr.html, Las Cruces, NM, 11-14 December 1995.

OTHER:

Baer, W., "Latitude Longitude Based Global Perspective View Generator," developed for TEXCOM Ft. Hunter Liggett,and TRAC Monterey, (SGI based C software program).

Baer, W. and Reed, C., "Terrain Database Initialization and Conversion Toolbox," developed for TEXCOM Ft. Hunter Liggett and MISC Huntsville, AL, (SUN based C software Program).

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Parallel processing, scientific visualization, battlefield simulation, environmental effect

COMPUTER-AIDED PROTOTYPING APPLIED TO
ARMY TACTICAL MISSILE COMMAND SYSTEM (ATACMS)
Valdis Berzins, Professor
Luqi, Professor
Department of Computer Science
Sponsor: Army Research Laboratory

OBJECTIVE: The Computer-Aided Prototyping System (CAPS) is an integrated software development environment aimed at rapidly prototyping hard real-time embedded software systems, such as missile guidance systems, space shuttle avionics systems, robots, automated telecommunications systems, computer-controlled vehicles, and computer-controlled consumer appliances such as microwave ovens and sewing machines. The objective of this project is to use the Computer-Aided Prototyping System developed at the Naval Postgraduate School to evaluate and refine the requirements for the Army Tactical Missile System. This will improve the quality of the product and its interoperability across different branches of DoD.

SUMMARY: This project focuses on the analysis, modeling, and prototyping of the requirements of the Army Tactical Missile System. We analyze the draft MOA of the ATACMS and use CAPS to develop a software prototype to capture the dynamic aspects of the requirements. The requirements are then refined through an iterative prototyping process characterized by exploratory design and extensive prototype evolution.

PUBLICATION:

Berzins, V. and Luqi, "Computer-Aided Prototyping Applied to ATACMS," Progress Report, Naval Postgraduate School, Monterey, CA, November 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Embedded system, software requirements, computer-aided software development

COMPUTER SCIENCE

COMPUTER AIDED PROTOTYPING SYSTEM FOR THE DEVELOPMENT AND EVOLUTION OF HARD REAL-TIME EMBEDDED SYSTEMS

Valdis Berzins, Professor
Luqi, Professor
Man-Tak Shing, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This research focuses on the formal techniques to support the development and maintenance of reliable software for distributed real-time systems typical of C3 applications. Major objectives of this work are to develop improved methods and sophisticated automated environments for engineers to effectively produce and evaluate prototypes to support an iterative rapid prototyping process for formulating and assessing the requirements and for project managers to plan, schedule and audit changes as system evolution.

SUMMARY: This project studied formal models and automated tools for the specification, development, and evolution of distributed hard real-time systems typical of C3 applications. It built upon the fundamental results obtained in the CAPS research in past years. In FY95, the design of code structure for integrating Ada Abstract Data Types with the Object Oriented Database schema was completed, thus solving the main difficulty in implementing the Evolution Control System. The fundamental issues in distributed hard real time scheduling and developed the software architecture for distributed real-time systems were investigated. An automated Reusable Components Specification Generator was designed and developed which examines each declaration contained in an Ada95 Package Specification and creates a corresponding PSDL specification. This tool allows the CAPS software base to be populated much faster utilizing existing DOD Ada software libraries such as the CAMP, ASSET, RAPID, and CRSS libraries. This tool has demonstrated its effectiveness by translating several complex components of the Common Ada Missile Packages into PSDL specifications.

PUBLICATION:

Shing, M. and Luqi, "Functional Specification and Prototyping for a Generic C3I Workstation," Proceedings of the First International Symposium on Command and Control Research and Technology, pp. 119-131, Washington, DC, 19-22 June 1995.

THESES DIRECTED:

Eagle, C. S., "Tools for Storage and Retrieval of Ada Components in a Software Base," Master's Thesis, March 1995.

Cordeiro, M., "Distributed Hard Real-Time Scheduling for a Software Prototyping Environment," Ph.D. Dissertation, March 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Hard real-time, embedded system, computer-aided software development, software evolution, rapid prototyping

COMPUTER SCIENCE

AUTOMATICALLY COMBINING
CHANGES TO SOFTWARE SYSTEMS

Valdis Berzins, Professor
Department of Computer Science
Sponsor: Army Research Office

OBEJCTIVE: Combining changes to software is a fundamental problem in software engineering with widespread applications in the design and evolution of software systems. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. We seek to develop both theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The proposed work has important potential applications to software maintenance, view integration in specifications, version control in engineering databases, and multiple inheritance in specification or programming languages. This is a continuing project.

SUMMARY: An improved change merging method for the prototyping language PSDL was developed. The novel features of this language are hard real-time constraints, parallel computation, and nondeterminism. The improvement is concerned with recovering the structure of a hierarchical design. The original version of the PSDL change merging method is based on prototype slicing. To achieve accuracy, the original method flattened the hierarchical design structures into a single large graph structure. This is useful for execution, but not as a basis for further software development, because the resulting designs are to complex for people to understand, analyze, and modify. The improved method uses the original approach and then reconstructs a new hierarchical design structure by separately merging changes to the hierarchy and then factoring the merged monolithic design according to the merged description of the hierarchy. This method is based on a new Brouwerian algebra model of design hierarchies. The new approach also includes an automatic method for recovering from merging conflicts. This is the first automatic solution to this problem that has appeared in the research literature.

PUBLICATIONS:

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based Change-Merging of Software Prototypes," Proceedings of Computer in Engineering Symposium, Houston, TX, PD-Vol.67, Software Systems in Engineering, ASME, (D. Cooke, et. al., ED.) pp. 87-92, 29 January - 1 February 1995.

Luqi, Goguen, J., Berzins, V., and Dampier, D., "Engineering Support for Software Evolution," Proceedings of Computer in Engineering Symposium, Houston, TX, PD-Vol.67, Software Systems in Engineering, ASME 1995, (D. Cooke, et. al., ED.) pp. 161-171, 29 January - 1 February 1995.

Berzins, V. and Luqi, "Software Evolution in Prototyping," Proceedings of the Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

Berzins, V. and Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, pp. 135-150, Vol.6, No. 1-2, to appear in 1996.

Berzins, V., "Recombining Changes to Software Specifications," Proceedings of the 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, to appear in June 1996.

CONFERENCE PRESENTATIONS:

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based Change-Merging of Software Prototypes," Computers in Engineering Symposium, Houston, TX, 29 January - 1 February 1995.

Luqi, Goguen, J., Berzins, V., and Dampier, D., "Engineering Support for Software Evolution," Computers in Engineering Symposium, Houston, Texas, 29 January - 1 February 1995.

Berzins, V. and Luqi, "Software Evolution in Prototyping," Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

OTHER:

Berzins, V., "Recombining Changes to Software Specifications," 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, forthcoming in June 1996.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software evolution, change merging, automation

INTEROPERABLE DATABASE SYSTEMS
David K. Hsiao, Professor
C. Thomas Wu, Associate Professor
Department of Computer Science
Sponsor: Naval Air Warfare Center - Weapons Division

OBJECTIVE: This is a part of ongoing research project in the area of interoperable, heterogeneous database systems. Our main objective for this year is to develop object-oriented interface to our prototype backend multi-lingual and multi-model backend database systems. We will redesign an EWIR (Electronics Warfare Information Retrieval) database using a generic object-oriented data model implement it using the object-oriented interface we will develop.

SUMMARY: Object-oriented interface was implemented. As a part of this implementation work, we identified components of attribute-based kernel system that need to be modified. We redesigned EWIR database using a generic object-oriented data model. We implemented the object-oriented EWIR database using our object-oriented interface.

PUBLICATION:

Hsiao, D.K., "Strategies in the Microprocessor Industry to TCP/IP Interconnecting: Concepts, Architecture, Protocols, and Tools," Encyclopedia of Microcomputers, (Editors: A. Kent, W. Williams, C. M. Hall, and R. Kent), Marcel Dekker, Inc., 1995.

THESES DIRECTED:

Graves, T.C., LT, USN, "Graphical User Interface Design for NTCSSAM: Shipboard Administrative Requirements," Master's Thesis, March 1995.

Badgett, R.B., CDR, USN, "The Design and Implementation of Object-Oriented Data Definition Language," Master's Thesis, September 1995.

Clark, R.E., LT, USN and Yildrirm, N., LT JG, Turkish Navy, "The Instrumentation of a Kernel DBMS for the Execution of Kernel Transactions Equivalent to Their Object-Oriented Transactions," Master's Thesis, September 1995.

Barbosa, C.M., LT, USN and Kutlusan, A., LT JG, Turkish Navy, "The Design and Implementation of a Compiler for the Object-Oriented Data Manipulation Language," Master's Thesis, September 1995.

COMPUTER SCIENCE

Stephens, M.W., LCDR, USN, "The Design and Implementation of Object-Oriented Data Manipulation Language," Master's Thesis, September 1995.

Senocak, E., LT JG, Turkish Navy, "The Design and Implementation of Real-time Monitor for Object-Oriented Interface," Master's Thesis, December 1995.

Kellett, D.A., LCDR, USN and Kwon, T. W., CAPT, Korean Army, "Supporting the Object-Oriented Database on The Kernel Database System," Master's Thesis, September 1995.

Ramirez, L.M., LT, USN and Tan, R., LT JG.Turkish Navy, "The Design and Implementation of a Compiler for the Object-Oriented Data Manipulation Language," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Database, user-interface, visual query language

TESTING OF AND APPLICATIONS FOR
HIGH ASSURANCE SECURE SYSTEMS
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The principle focus of this research was to investigate applications for high assurance distributed systems. A concurrent objective was to examine covert channels in an evaluated trusted system.

SUMMARY: A study was conducted of a multilevel file system developed for execution on a high assurance platform. The objective was to design the file system so that, although it is a multilevel database, it could be managed by single level entities, viz. subjects, executing on behalf of authorized users. Design issues considered included use of single level volumes and instantiation of file system data structures for previously unencountered access classes. The challenge of providing a system that met practical requirements resulted in a number of interesting tradeoffs.

A follow-on to the above analysis was a preliminary design for a high assurance trusted file service using commercial-off-the-shelf (COTS) products to create a local area network (LAN). The file server will be a major commercial network file system ported to a high assurance multilevel secure platform. Untrusted workstations will be equipped with a trusted computing base hardware extension that will permit user identification and authentication via a trusted path from the workstation, and will also assure conformance with object reuse requirements. Workstation users will be able to share file service resources as permitted by the policy being enforced by the underlying high assurance base. The untrusted workstations will be able to execute their users favorite COTS applications without modification. Extensions to the architecture to incorporate Multilevel Information System Security Initiative (MISSI) products in support of the DefenseMessage System (DMS) have been outlined.

A study of covert channels exploitable on the Trusted Solaris platform available from Sun Microsystems revealed a number of system resources that could be used to pass information from high to low sensitivity levels.

PUBLICATION:

Irvine, C.E, "A Multilevel File System for High Assurance," Proceedings of the 1995 IEEE Symposium on Security and Privacy, Oakland, CA, pp. 78-87, May 1995.

18

COMPUTER SCIENCE

CONFERENCE PRESENTATION:

Irvine, C.E., "A Multilevel File System for High Assurance," IEEE Symposium on Security and Privacy, Oakland, CA, May 1995.

THESIS DIRECTED:

DeJong, R.J., "A Study of Covert Channels in a Trusted Unix System," Master's Thesis, March 1995.

OTHER:

Irvine, C.E. and Schell, R.R., "The Technical Foundations of Balanced Assurance for Trusted Systems," paper in progress.

Anderson, J.P and Irvine, C.E., "A High Assurance Multilevel File Server for Off-The-Shelf Workstation Applications and Secure Messaging," white paper.

DOD KEY TECHONOLOGY AREA: Computing and Software

KEYWORDS: INFOSEC, multilevel security, distributed systems, applications software

INFOSEC RESEARCH AND EDUCATION PROGRAM
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The broad objectives of this program are to pursue computer security research at the Naval Postgraduate School, provide computer security and INFOSEC education as part of the academic program for military officers, and support a computer security specialization for military officers.

SUMMARY: In early 1995 Irvine and Volpano began a collaboration to study information flow in software. It is now an ongoing project that, in late 1995, ARPA agreed to fund for two years. The work will be done at NPS. Faculty and staff participants include Dennis Volpano, Hal Fredericksen, and Paul Clark. It is aimed at developing a tool for the automatic detection of insecure information flow in software. The tool is expected to be applied to existing code in order to detect places where the software is leaking sensitive information. A formal system, in which it is possible to prove code is secure, has been developed. The system has been shown sound. The system can be implemented, using standard type inference techniques, to construct proofs automatically if they exist. Such a tool is expected to have both military and commercial applications. On the commercial side, Web agent software is a candidate for such analysis, given its ability to execute on client machines with user privileges.

An examination of information hiding in imagery was begun as a collaboration between Irvine and Frederickson. A technique known as steganography permits information to be hidden in digital output in a manner that is difficult or impossible to detect by either human or automated techniques. The exploitation of steganography in automated systems storing classified information would permit the exfiltration of sensitive data. This research is exploring the use of encoding techniques to ensure the robustness of surreptitiously exported data against standard image compression algorithms. Possible techniques to foil attempts at steganography in imagery are under investigation.

Paul Clark is working with students and faculty involved in both research efforts to provide technical support in the computer security laboratory and associated facilities.

PUBLICATION:

Irvine, C. and Volpano, D., "A Practical Tool for Developing Trusted Applications," Proceedings of the 11th Computer Security Applications Conference, New Orleans, LA, pp. 190-195, December 1995.

CONFERENCE PRESENTATIONS:

Volpano, D. and Irvine,C., "An Environment for Developing Secure Software," presented at the 1995 IEEE Symposium on Security and Privacy, Oakland, CA, May 1995.

Volpano, D., "Secure Flow Typing", IFIP WG2.8, http://www.cs.chalmers.se/WG2.8/meetings/aspenaes-95/, September 1995.

Irvine, C. and Volpano, D., "A Practical Tool for Developing Trusted Applications," presented at 11th Computer Security Applications Conference, New Orleans, LA, December 1995.

OTHER:

Volpano, D., Smith, G., and Irvine, C.E, "A Sound Type System for Secure Flow Analysis," submitted.

Irvine, C.E. and Volpano, D., "Flow-Secure Software Through Typing," paper in progress.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Information flow, software certification, covert channels, multilevel security

SUPPORT FOR NAVAL POSTGRADUATE SCHOOL INFOSEC RESEARCH PROGRAM
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The objective of this research is to support the development of a center for research and education in information systems security at the Naval Postgraduate School. The effort is intended to provide military officers basic and advanced education in the area of computer and information systems security. The program is intended to be a continuing source of high-quality information systems security research focusing on problems of critical importance to the military services. A goal will be to obtain military officers with advanced degrees in technical disciplines for identified billets within the National Security Agency.

SUMMARY: Staff participants in this effort include Paul Clark. This is the first increment of a projected five-year effort to develop a center of excellence for research and education in computer security at the Naval Postgraduate School. Although in its preliminary stages, progress has been made toward strengthening the computer security track in a number of ways. First, several faculty research programs in computer security benefit from laboratory support. The program will help faculty to improve existing courses and develop new ones. Finally modest support for hardware and software maintenance and supplies in the computer security laboratory will be possible. As this program evolves, more detailed reports are anticipated.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Information flow, software certification, covert channels, multilevel security

COMPUTER SCIENCE

INFOSEC EDUCATION PROGRAM
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: Defense Information Systems Agency

OBJECTIVE: The objective of this effort was to initiate development of a prototype INFOSEC education program at the Naval Postgraduate School that would be suitable for export to other teaching facilities and agencies within DoD. The intended audience for this program will be technically competent individuals who are not computer scientists.

SUMMARY: A Computer Security Series has been outlined which is intended to familiarize non-computer science students with: the basic principles of computer security; the threat of malicious artifices in computer systems, the synergy between computer security and cryptographic techniques; management issues for secure systems; the relationship between security policies and security enforcement in operational systems; the use of commercial-off-the-shelf (COTS) products in secure systems architectures, management, and life cycle issues for INFOSEC systems. The intent is to equip graduates to make informed judgments regarding current and future information systems and information warfare (IW). When complete, the series will include four Computer Science courses:

- CS3600 Introduction to Computer Security
- CS3670 Management of Secure Systems
- CS3680 Building Defensible Computer Systems
- CS3690 Applying INFOSEC Systems

This effort focused on the first two of these courses. CS3600 was fully developed and taught for the first time in the Fall quarter of 1995. It includes a syllabus, notes, readings, and laboratory exercises. A detailed outline for CS3670 was developed. Classroom testing of CS3600 revealed several areas for additional refinement: include fewer topics in order to provide more detailed coverage; move certain management-related topics to CS3670, Management of Secure Systems; and make laboratory exercises more granular so that students have longer to experiment with each new concept.

As technology in information systems security evolves, an ongoing effort will be needed to include in each course new material relevant to current DoD INFOSEC concerns. Faculty and staff participants in this research included Prof. Roger Stemp and Paul Clark.

OTHER:

Products of this effort included a course syllabus, notes, supplemental readings, and a laboratory tutorial for CS3600, Introduction to Computer Security. A course syllabus for CS3670, Management of Secure Systems, and detailed course outline was developed.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: INFOSEC, computer security education

21

COMPUTER SCIENCE

AUTONOMOUS MOBILE ROBOT SYSTEM
FOR ARTIFICIAL INTELLIGENCE (AI) EDUCATION
Yutaka Kanayama, Professor
Department of Computer Science
Sponsor: Army Artificial Intelligence Center

OBJECTIVE: The project goal is to develop an intelligent autonomous mobile robot for AI education. Military students will be able to have hands-on experiences with a real system consisting of an indoor mobile vehicle "Yamabico-11" and its high-level robot language MML.

SUMMARY: Theories and real-systems in four areas were developed: motion planning, sonar, and computer vision. Furthermore, the PI started research of a new autonomous vehicle "rotary vehicle."

Progress was made in the motion planning theory. Dividing a world using "borders" into regions was found so that the global motion planning problem is converted to an approximated graph search algorithm. This is the major portion of Joe Kovalchik's Ph.D. dissertation work. The same world decomposition is used for the local motion planning as well. This work is the central portion of Chien-Liang Chuang's Ph.D. dissertation. These total motion planning algorithm was successfully implemented on the autonomous mobile robot "Yamabico". This accomplishment is a fundamental software basis for the forthcoming further development.

The Yamabico's sonar software system was also tested and re-designed to make a perfect basis. The fundamental work of automatic localization correction using linear feature extraction and geometric model were done. This was done by an Egyptian Ph.D. student, Mahmoud Wahdan. This is a part of his main dissertation work of motion planning using automatic localization correction.

The image understanding hardware/software system was also implemented in this year into a more robust form. Two students Khaled Morsy (another Egyptian Ph.D. student) and Leonard Remias improved the stability and efficiency of the IU system.

A "rotary vehicle" is a completely novel wheeled vehicle architecture which was born from the PI's vehicle kinematics theory. This autonomous vehicle has a flexible motion capability which ordinary vehicle do not possess and has a stronger traction on soft soil and on the sand. Thus it will be extremely useful for military operations as well as mine searching tasks. A patent is applied through the Naval Postgraduate School and the Navy entitled as "Method of Controlling a Vehicle to Make a Combination of Arbitrary Translational and Rotational Motions" on November 6, 1995 with an application number of 08/553,904. The PI ordered a rotary vehicle to Mitsubishi Heavy Industries, since the company is the only one that has the expertise of fabricating the complex vehicle. The vehicle is expected in March.

PUBLICATION:

Kanayama, K. and Hartman,B., "Smooth Local Path Planning for Autonomous Vehicles," International Journal of Robotics Research, to appear 1996.

CONFERENCE PRESENTATIONS:

Kanayama, Y., Kovalchik, J., Chuang, C., and Kelbe, F., "Motion Planning for Autonomous Mobile Robots," Proceedings Autonomous Vehicles in Mine Countermeasures Symposium, pp. 8-74 - 8-80, in Monterey, CA, 4-7 April 1995.

Kanayama, Y., McGhee, R. B., Yoneda, K., Suzuki, K., McMillan, S., Takahashi, H., and M Iwasaki, M., "An International Joint Research Project on an Autonomous Underwater Walking Robot," Proceedings in International Symposium on Coastal Ocean Space Utilization, pp. 181-192, Yokohama, Japan, 30 May - 2 June 1995.

COMPUTER SCIENCE

Suzuki, K.,Yoneda, K., Kanayama, Y., Takahashi,Tomoyoshi, H., and Takeuchi, T., "Experimental Study of Versatile Motion Planning for a Six Legged Robot over Uneven Terrain," Video Proceedings in IEEE International Conference on Robotics and Automation, Nagoya, Japan, 21-27 May 1995.

THESES DIRECTED:

Kisor, J.C., "Integration of an Image Hardware/Software System into an Autonomous Robot," Master's Thesis, March 1995.

Jun, S.J., "The Local Motion Planning for an Autonomous Mobile Robot," Master's Thesis, September 1995.

Kovalchik, J., "Layered Motion Planning for Autonomous Mobile Robots Using Free Space Decomposition and Steering Functions," Ph.D, September 1995.

Chuang, C. -L., "Layered Safe Motion Planning for Autonomous Vehicles," Ph.D. Dissertation, September 1995.

PATENT APPLICATION:

Kanayama, Y., "Method of Controlling a Vehicle to Make a Combination of Arbitrary Translational and Rotational Motions," Application Number: 08/553,904, filed 6 November 1995.

OTHER:

Yoneda, K., Kanayama, Y., and Suzuki, "Variable Parameter Forward Wave Gait for a Radially Symmetric Six Legged Walker," submitted to the IEEE Transaction of Robotics and Automation, September 1995.

Yoneda, K., Suzuki, K., Kanayama, Y., Takahashi, H., and Akizono, J., "Gait and Foot Trajectory Planning for Versatile Motion of a Six Legged Robot," submitted to the Advanced Robotics, December 1995.

Kanayama, Y. and Fahroo, F., "Smooth Motion Planning for Non-Holonomic Vehicles," submitted in December 1995 to the Second International Workshop on Algorithmic Foundation of Robotics, in Toulouse, France, forthcoming in July 1996.

DOD KEY TECHNOLOGY AREAS: Other (Robotics)(Software Engineering)

KEYWORDS: Robotics, autonomous robot, AI education, motion planning, rotary vehicle

RUSSIAN SCHOLAR EXCHANGE
Ted Lewis, Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: To develop the world's first portable parallel programming environment.

SUMMARY: This two-year joint USA-Russia project investigates new parallel programming language concepts for general-purpose parallel programming. It addresses: 1) both large-grained and fine-crained parallelism, 2) both control-parallel and data-parallel paradigms, 3) both static and dynamic task creation, and 4) target machine independence. An environment is being constructed that will use novel progam visualization and incremental compiling techniques to increase a programmer's understanding of the parallel application programs being constructed.

COMPUTER SCIENCE

The tangible results of this work, in addition to the usual scientific publications are: 1) exchange of technology between USA and Russia, 2) advancement of parallel programming language research, and 3) production of a portable parallel programming language plus its proganuning environment. This will have long-term relevence to DoD systems that require very high powered performance, e.g. real-time modeling and simulation.

PUBLICATIONS:

Lewis, T., Object-Oriented Application Frameworks, Prentice-Hall, 225 pp., January 1995.

Lewis,T., Visual Object-Oriented Programming (with M. Burnett, A. Goldberg), Prentice-Hall, 300 pp., June 1995.

Zhu, J., Jackson, Lewis, T., and Wilson, R.L., "Design and Analysis of Hard Real-Time Applications in a Uniprocessor Environment," EEE Software, May 1995.

Lewis, T., "Where is Client/Server Computing Headed?," IEEE COMPUTER, Vol. 28, No. 4, pp. 49-55, April 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Parallel programming, fine-grained parallelism, international cooperation

INVESTIGATION OF THE ARMY'S DATA NETWORK TRAFFIC LOADING
G. M. Lundy, Associate Professor
Department of Computer Science
Sponsor: Joint Tactical Area Communication System

OBJECTIVE: To estimate the future traffic load for the Army's Tactical Packet Network, and determine if the current capacity is sufficient to carry this load. If not, then attempt to estimate how much capacity is needed.

SUMMARY: The Army currently has a packet switched network called the TPN, for Tactical Packet Network. This network runs on top of the MSE, or Mobile Subscriber Network. These networks function together to carry both voice and data traffic for the modern battlefield Army. In this work, the structure and capacity of these networks, and their current usage will be studied. Future usage will be projected as well as an estimate of what the future needed capacity of the network should be. As a result, the Army an estimate of how much, if any, it needs to expand the capacity of its network.

DOD KEY TECHNOLOGY AREA: Command, Control and Communications (C3)

KEYWORDS: Packet-switching, high speed networks, wireless communications

FORMAL MODELS USED FOR AUTOMATION IN SOFTWARE DEVELOPMENT
Luqi, Professor
Valdis Berzins, Professor
Department of Computer Science
Sponsor: Army Research Office

OBJECTIVE: The objective of the proposed research is the design of an integrated set of formal models and methods for automating a wide range of design and development tasks for real-time systems. The methods we use will focus on automation of design activities that appear in an evolutionary prototyping approach to software

development. This research intends to use the state-of-the-art formal methods in software engineering to construct a cohesive set of formal models. These models are used to create and to unify a computational model to support automated processes for computer aided prototyping.

Mathematical models for implementing a set of automated and integrated software tools will also be developed. This research will combine very-high-level specification abstractions and concepts with formal real-time models, automated management of software design data and human resources, transformations, change merging, and automated retrieval of reusable software components to provide automated methods for generating real-time programs and for coordinating teams of developers. The significance of the research is to improve productivity and software quality by enabling a higher level of automation in software development. The result of this research will broaden the definition of automatic programming and will make automatic programming a practical approach for increasing productivity in the software life cycle. Automated decision support functions used will ensure software quality by decreasing the human effort required and minimizing the incidence of human error. The approach controls the complexity and high degrees of freedom of the software process by using computer-aid.

Earlier user feedback for validating and refining specifications through trial use of operational system prototypes experimentally ensures that the formal specifications corresponds to user needs. Maintenance costs will be minimized by reducing the need to repair requirements errors after system deployment and by using specification-based automatic program correction methods sensitive to both syntax and semantics.

SUMMARY: This project is investigating formal models that can support automated methods supporting software development. The focus has been on automation support for requirements elicitation, particularly for prototyping, and on automation support for software evolution, particularly for automatically detecting the need for software maintenance actions using non-monotonic logic, for capturing requirements dependencies and justifications using the REMAP extension of the IBIS model, for automated generation of schedules for hard real-time software, for retrieval of reusable software components, for combining several modifications to a system, and for using specifications in the design of software architectures.

PUBLICATIONS:

Luqi and Cooke, D., "How to Combine Nonmonotonic Logic and Rapid Prototyping to Help Maintain Software," International Journal of Software Engineering and Knowledge Engineering, Vol. 5, Number 1, pp. 89-118, March 1995.

Ramesh, B. and Luqi, "An Intelligent Assistant for Requirements Validation for Embedded Systems," Journal of Systems Integration, Vol. 5, No. 2, pp. 157-177, 1995.

Luqi and Shing, M., "Real-Time Scheduling for a Prototyping Language," Journal of Systems Integration, special issue on Computer-Aided Prototyping,Vol. 6, No. 1, pp. 41-72, to appear 1996.

Goguen, J., Nguyen, D., Meseguer, J., Luqi, Zhang, D., and Berzins, V., "Software Component Search," Journal of Systems Integration, special issue on Computer Aided Prototyping,Vol. 6, No. 2, pp. 93-134, to appear 1996.

Berzins, V. and Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1-2, pp. 135-150, to appear 1996.

Luqi and Goguen, J., "Suggestions for Progress in Software Development and Evolution," to appear, IEEE Software.

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based Change-Merging of Software Prototypes," Proceedings of Computers in Engineering Symposium, Houston, TX, Software Systems in Engineering, (D. Cooke et. al, ED.) PD-Vol.67, pp. 87-92, ASME, 29 January - 1 February 1995.

Luqi, Goguen, J., Berzins, V., and Dampier, D., "Engineering Support for Software Evolution," Proceedings of Computers in Engineering Symposium, Houston, TX, PD-Vol.67, Software Systems in Engineering, ASME 1995,(D. Cooke et. al., ED.) pp. 161-171, 19 January - 1 February 1995.

Dampier, D., Kindl, M., Byrnes, R., and Luqi, "Rapid Prototyping of Army Embedded Software Systems," Proceedings of Seventh Annual Software Technology Conference, Salt Lake City, UT, 1-14 April 1995.

Goguen, J. and Luqi, "Formal Methods and Social Context in Software Development," Proceedings of the Sixth International Joint Conference on the Theory and Practice of Software Development, TAPSOFT95, pp. 62-81, Aarhus, Denmark, 22-26 May 1995.

Shing, M. and Luqi, "Functional Specification and Prototyping for a Generic C3I Workstation," Proceedings of 1995 Symposium on Command and Control Research and Technology, Washington, DC, pp. 119-131, 19-23 June 1995.

Berzins, V., Luqi, and Shing, M., "Computer Aided Prototyping System," Proceedings of 1995 International Conference on Software Engineering and Data Engineering, Washington DC, pp. 499, 22-24 June 1995.

Luqi and Berzins, V., "Logic, Software Engineering and Prototyping," Proceedings of the Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

Berzins, V. and Luqi, "Software Evolution in Prototyping," Proceedings of the Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

Zhang, D. and Luqi, "Formal Analysis of Inconsistency and Redundancy in Knowledge Bases," Proceedings of IJCAI'95 Workshop on Validation & Verification of Knowledge Based Systems, Montreal, Quebec, Canada, pp. 110-116, 19 August 1995.

Luqi and Berzins, V., "Software Architecture in Computer-Aided Prototyping," Proceedings of 1995 Monterey Workshop on Increasing the Practical Impact of Formal Methods in Computer Aided Software Development: Software Architecture, Monterey, CA, 12-14 September 1995.

Luqi, "Specification Based Software Architecture", Proceedings of 1995 Monterey Workshop on Increasing the Practical Impact of Formal Methods in Computer Aided Software Development: Software Architecture, Monterey, CA, 12-14 September 1995.

Luqi, "Specifications in Software Prototyping," Proceedings of the 8th International Conference on Software Engineering and Knowledge Engineering, Lake Tahoe, CA, 10-12 June 1996.

CONFERENCE PRESENTATIONS:

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based Change-Merging of Software Prototypes", Computers in Engineering Symposium, Houston, TX, 29 January - 1 February 1995.

Luqi, Goguen, J., Berzins,V., and Dampier, D., "Engineering Support for Software Evolution," Computers in Engineering Symposium, Houston, TX, 29 January - 1 February 1995.

Dampier, D., Kindl, M., Byrnes, R., and Luqi, "Rapid Prototyping of Army Embedded Software Systems," Seventh Annual Software Technology Conference, Salt Lake City, UT, 9-14 April 1995.

Goguen, J. and Luqi, "Formal Methods and Social Context in Software Development," Sixth International Joint Conference on the Theory and Practice of Software Development, TAPSOFT95, Aarhus, Denmark, 22-26 May 1995.

COMPUTER SCIENCE

Shing, M. and Luqi "Functional Specification and Prototyping for a Generic C3I Workstation," 1995 Symposium on Command and Control Research and Technology, Washington DC, 19-23 June 1995.

Berzins, V., Luqi, and Shing, M., "Computer Aided Prototyping System," 1995 International Conference on Software Engineering and Data Engineering, Washington DC, pp. 499, 22-24 June 1995.

Luqi and Berzins, V., "Logic, Software Engineering and Prototyping," Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

Berzins, V. and Luqi, "Software Evolution in Prototyping," Logic and Software Engineering Workshop, Software Institute, National Academy of Science, Beijing, China, 15 August 1995.

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Luqi and Berzins, V., "Software Architecture in Computer-Aided Prototyping," 1995 Monterey Workshop on Increasing the Practical Impact of Formal Methods in Computer Aided Software Development: Software Architecture, Monterey, CA, 12-14 September 1995.

Luqi, "Specification Based Software Architecture," 1995 Monterey Workshop on Increasing the Practical Impact of Formal Methods in Computer Aided Software Development: Software Architecture, Monterey, CA, 12-14 September 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software engineering, formal methods, automation

NATIONAL SCIENCE FOUNDATION PRESIDENTIAL YOUNG INVESTIGATOR
Luqi, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: The goal of this research is to enable rapid prototyping of hard real time systems via a computer aided prototyping system (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly, to be executed, and to be analyzed for eliciting and validating the requirements. The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and real-time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging.

SUMMARY: The main research problems we have are developing abstract models and implementation techniques based on formalized specifications. Progress during this year has been mainly in the areas of automated support for software evolution, multiprocessor models for real-time systems, software transformation and software reuse. In FY95, abstract models were refined and methods developed for hard real-time scheduling, evolution of software requirements, computer- aided software reuse and retrieval, software change merging, software architectures, and the use of logic

to support software prototyping. These tools together form an integrated software environment CAPS aimed at rapidly prototyping hard real-time embedded software system to support software evolution as well as initial development.

PUBLICATIONS:

Luqi and Cooke, D., "How to Combine Nonmonotonic Logic and Rapid Prototyping to Help Maintain Software," International Journal of Software Engineering and Knowledge Engineering, Vol. 5, Number 1, pp. 89-118, March 1995.

Ramesh, B. and Luqi, "An Intelligent Assistant for Requirements Validation for Embedded Systems," Journal of Systems Integration, Vol. 5, No. 2, pp. 157-177, 1995.

Luqi, Shing, M., "Real-Time Scheduling for a Prototyping Language," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1, pp. 41-72, to appear 1996.

Goguen, J., Nguyen, D., Meseguer, J., Luqi, Zhang, D., and Berzins, V., "Software Component Search," Journal of Systems Integration, special issue on Computer Aided Prototyping,Vol. 6, No. 2, pp. 93-134, to appear 1996.

Berzins, V. and Dampier, D., "Software Merge: Combining Changes to Decompositions," Journal of Systems Integration, special issue on Computer-Aided Prototyping, Vol. 6, No. 1-2, pp. 135-150, to appear 1996.

Luqi and Goguen, J., "Suggestions for Progress in Software Development and Evolution,"to appear, IEEE Software.

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based .Change-Merging of Software Prototypes," Proceedings of Computers in Engineering Symposium, Houston, TX, Software Systems in Engineering, (D. Cooke et. al, ED.), PD-Vol.67, pp. 87-92, ASME, 29 January - 1 February 1995.

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CONFERENCE PRESENTATIONS:

Dampier, D., Berzins, V., Luqi, Shing, M., Dolk, D., and Rasmussen, C., "A Slicing Method for Semantics-Based Change-Merging of Software Prototypes," Computers in Engineering Symposium, Houston, Texas, 29 January - 1 February 1995.

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Zhang, D. and Luqi, "Formal Analysis of Inconsistency and Redundancy in Knowledge Bases," IJCAI'95 Workshop on Montreal, Quebec, Canada, 19 August 1995.

THESES DIRECTED:

Eagle, C., "Tools for Storage and Retrieval of Ada Software Components in a Software Base," Master's Thesis, March 1995. (Received Grace Murray Hopper Award)

Nguyen, D., "An Architectural Model for Software Component Search," Ph.D. Dissertation, December 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software engineering, formal methods, automation

COMPUTER SCIENCE

WORKSHOP ON BUILDING SYSTEMS WITH SPECIFICATION-BASED COMPONENTS
Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The purpose of the workshop is to assess current efforts, to identify results and directions for increasing the degree of automation, to build a common understanding about the integration of methods and tools, and ultimately to help bring formal methods into practical use. The 1995 Monterey Workshop focuses on specification-based software architectures, because it is a current and practically significant large-scale problem that promises to be amenable to formalization. Some aspects of this problem are: formalizing the requirements on the components that can fit in a given slot in an architecture, developing methods for realizing or checking those requirements, formalizing types of connections, and methods for converting one kind of connection into another, and developing methods for systematically generalizing architectures. The workshop will help researchers working on formal methods for different aspects of software development to understand recent progress on formalizing other, related aspects of the problem, and to identify issues from those other areas that have direct implications for their own work.

SUMMARY: The workshop had a series of presentations related to different aspects of specification-based architecture, and extensive discussions. Workshop papers are included in the workshop proceedings. The workshop schedule was organized as follows:

Day 1: Luqi, Naval Postgraduate School: Welcome and Introduction Waugh, SEI/CMU: Evolutionary Design of Complex Software DeMarco, Atlantic Systems Guild: On Systems Architecture Tsai, Univ. of Illinois at Chicago: A Knowledge Based Approach for Specification-Based Software Architectures

Day 2: Berzins, Naval Postgraduate School: Software Architectures in Computer-Aided Prototyping; Goguen, Oxford University: Algebraic Specification-Based Software Architectures; Dampier, Army Research Laboratory: Specification Merging for Software Architectures; Elements, SEI/CMU: Formal Methods in Describing Architectures

Day 3: Mok, Univ. of Texas at Austin: Real Time Aspects of Software Architecture; Robertson, University of Edinburgh: Lightweight Formal Methods; Cooke, Univ. of Texas at El Paso: The Software Architecture for the Analysis of Geographic and Remotely Sensed Data

The conclusions of each session are summarized by the reporters for the session, and the results are integrated into the article, "Summary of the `95 Monterey Workshop," on pages 107-112 of the workshop proceedings.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer-aided software development, software architectures, rapid prototyping

WORKSHOP ON FORMAL METHODS FOR SOFTWARE DEVELOPMENT
Luqi, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: The purpose of the workshop is to assess current efforts, to identify results and directions for increasing the degree of automation, to build a common understanding about the integration of methods and tools, and ultimately to help bring formal methods into practical use. The 1995 Monterey Workshop focuses on specification-based software architectures, because it is a current and practically significant large-scale problem that promises to be amenable to formalization. Some aspects of this problem are: formalizing the requirements on the components that can fit in a given slot in an architecture, developing methods for realizing or checking those requirements, formalizing types of

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Day 2: Berzins, Naval Postgraduate School: Software Architectures in Computer-Aided Prototyping; Goguen, Oxford University: Algebraic Specification-Based Software Architectures; Dampier, Army Research Laboratory: Specification Merging for Software Architectures; Clements, SEI/CMU: Formal Methods in Describing Architectures

Day 3: Mok, Univ. of Texas at Austin: Real Time Aspects of Software Architecture; Robertson, University of Edinburgh: Lightweight Formal Methods; Cooke, Univ. of Texas at El Paso: The Software Architecture for the Analysis of Geographic and Remotely Sensed Data

The conclusions of each session are summarized by the reporters for the session, and the results are integrated into the article, "Summary of the `95 Monterey Workshop," on pages 107-112 of the workshop proceedings.

PUBLICATION:

Luqi, "Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development," Proceedings of the 1995 Monterey Workshop - Specification-Based Software Architectures, Luqi, Naval Postgraduate School, Monterey, CA, 12-14 September 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer-aided software development, software architectures, rapid prototyping

A COMPUTER AIDED PROTOTYPING SYSTEMS
FOR REAL-TIME ADA 95 SOFTWARE
Luqi, Professor
Department of Computer Science
Sponsor: Ada Joint Program Office

OBJECTIVE: The Computer Aided Prototyping System (CAPS) is a software engineering environment designed to support the systematic development of Ada embedded software on commercial workstations. The development of release 1 of the CAPS system has been completed under the sponsorship of AJPO using Ada 83, and prototype versions of some of the CAPS tools have been validated by using them to generate an executable Ada prototype of the essential features of a C3I system. The initial pilot study has demonstrated that Ada prototypes of real-time systems can be generated rapidly and at low cost. The objective of the ATIP project is to convert these tools to Ada 95 and to extend them to take advantage of the new features of Ada 95 to generate better Ada applications software. These capabilities should contribute to the attractiveness of Ada 95 for use in government and industry.

COMPUTER SCIENCE

SUMMARY: In FY95, the design and implementation of the CAPS_Hardware_Model, Ds_Debug_Pkg, PSDL_Timer, PSDL_Timer_List, PSDL_Exception and PSDL_Streams packages was completed. These packages provide the abstract data types needed to support the CAPS generated Ada 95 control code for the prototypes. The CAPS_Hardware_Model package now uses GNAT.OS_Lib package instead of the SunAda U_Env, C_Strings, and A_Strings packages. The Ds_Debug_Pkg and PSDL_Exception packages now uses the Ada.String.Unbounded package instead of the SunAda A_Strings package. The PSDL FIFO streams, Sampled streams, and State streams are now implemented as Ada 95 Protected Objects. The performance of the new implementation was compared against the original task implementation empirically and found that the new implementation has achieved significant improvements in both timing and storage requirements. New components for CAPS scheduler were developed and the performance was studied extensively. The new component consists of several new and improved modules for generating the static and dynamic schedules. The new scheduler was applied to newly generated prototypes and the results showed that the new scheduling components run much faster and produce better quality schedules than previous ones. The design of the PSDL Specification Generator was completex, which automates the generation of PSDL specifications for Ada 95 reusable components that are developed outside the scope of the CAPS system. This new tool eliminates the labor-intensive task of generating PSDL specifications by hand, thus increases the use of Ada and reducing the chance of making errors in the specifications.

PUBLICATION:

Luqi and Shing, M., "Real-Time Scheduling For Software Prototyping," Journal of Systems Integration, Vol. 6, No. 1-2, to appear 1996.

THESES DIRECTED:

Eagle, C.S., "Tools for Storage and Retrieval of Ada Components in a Software Base," Master's Thesis, March 1995.

Cordeiro, M. "Distributed Hard Real-Time Scheduling for a Software Prototyping Environment," PhD Dissertation, March 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Hard real-time embedded system, computer-aided software development, software evolution, rapid prototyping

AN EXPERIMENTAL STUDY OF SOFTWARE ARCHITECTURES AND SOFTWARE REUSE FOR CONTROL OF UNMANNED UNDERWATER VEHICLES
Robert B. McGhee, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: The goal of this project is to investigate alternative software architectures for control of unmanned underwater vehicles, and to find effective means for archiving and retrieving software modules used to implement such software systems. The research is being conducted in cooperation with the Monterey Bay Aquarium Research Institute (MBARI), and with INRIA, a French Government Research Institute.

SUMMARY: This is a three-year project which began in January, 1994. During calendar year 1995, much of the work was focused on further development of the "Rational Behavior Model" (RBM) architecture, and its testing in the NPS "Phoenix" autonomous underwater vehicle (AUV). This work was successful, and is reported in [1-7]. A virtual world for Phoenix was successfully created, using advanced graphics workstations to simulate in real-time both the vehicle dynamics and its ocean environment [8]. This simulation includes a physical copy of the Phoenix control computer,

thereby enabling laboratory testing and evaluation of control software running in the target computer, without the expense and hazards associated with in-water experiments [9]. Finally, a small AUV navigation system (SANS) based on a combination of a low cost strapped down inertial measurement unit (IMU) and a miniaturized global positioning system receiver (GPS) [10,11] was successfully tested in Monterey Bay. Results obtained in all of these research areas were encouraging, and further software development and open water testing will be pursued in CY96.

PUBLICATIONS:

Healey, A.J., et al., "Evaluation of the NPS Phoenix Autonomous Underwater Vehicle Hybrid Control System," Proceedings of ACC'95, San Francisco, CA, June 1995.

Brutzman, D., "Virtual World Visualization for an Autonomous Underwater Vehicle," Proceedings of IEEE Oceans '95 Conference, San Diego, CA, pp. 1592-1600, 10-12 October 1995.

McGhee, R.B., et al., "An Experimental Study of an Integrated GPS/INS System for Shallow-Water AUV Navigation (SANS)," Proceedings of 9th International Symposium on Unmanned Untethered Submersible Technology, Univ. of New Hampshire, Durham, NH, pp. 153-167, 25-27 September 1995.

Byrnes, R.B., et al., "The Rational Behavior Model Software Architecture for Intelligent Ships: An Approach to Mission and Motion Control," Proceedings of American Society of Naval Engineers, to appear March 1996.

Marco, D.B., Healey, A.J., and McGhee, R.B., "Autonomous Underwater Vehicles: Hybrid Control of Mission and Motion," Journal of Autonomous Robots, to appear 1996.

Holden, M.J., "Ada Implementation of the Rational Behavior Model Software Architecture for the Phoenix AUV," Proceedings of 6th IEEE International Symposium on Robotics and Automation (ISRAM`96), Montpellier, France, to appear May 1996.

Marco, D.B., et al., "Control Systems Architecture, Navigation, and Communication Research Using the NPS Phoenix Underwater Vehicle," Proceedings of 6th IARP Workshop on Underwater Robotics, Toulon, France, to appear March 1996.

Healey, A.J., et al., "Implementation of a Coral/Petri Net Strategic Level on the NPS Phoenix Vehicle," Proceedings of 6th IARP Workshop on Underwater Robotics, Toulon, France, to appear March 1996.

Brutzman, D.P., et al., "NPS Phoenix AUV Software Integration and Open Water Testing," Proceedings of IEEE AUV'96 Symposium, Monterey, CA, to appear June 1996.

McMillan, S., Orin, D.E., and McGhee, R.B., "A Computational Framework for Simulation of Underwater Robotic Vehicle Systems," Journal of Autonomous Robots, to appear 1996.

Bachmann, E.R., et al., "Evaluation of an Integrated GPS/INS System for Shallow-Water AUV Navigation (SANS)," Proceedings of IEEE AUV '96 Conference, Monterey, CA, to appear June 1996.

THESES DIRECTED:

Brutzman, D.P., "A Virtual World for an Autonomous Underwater Vehicle," PhD Dissertation, , December 1994.

Holden, M.J., "da Implementation of Concurrent Execution of Multiple Tasks in the Strategic and Tactical Levels of the Rational Behavior Model for the NPS Phoenix Autonomous Underwater Vehicle," Master's Thesis, September 1995.

COMPUTER SCIENCE

Bachmann, E.R. and Gay, D.L., "Design and Evaluation of an Integrated GPS/INS System for Shallow-Water AUV Navigation," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Other (Battlefield Robotics)

KEYWORDS: Robotics, minehunting, autonomous underwater vehicles (AUV)

ADVANCED RESEARCH PROJECTS AGENCY (ARPA) SUPPORTED WORK
David R. Pratt, Assistant Professor
Department of Computer Science
Sponsor: Advanced Research Projects Agency

OBJECTIVE: NPSNET-IV.8 - will be formally released. This will be the first supported and CM version of NPSNET. During the next reporting period, the graduating students will be integrating their work into NPSNET and a formal Bug Tracking mechanism will be established.

SUMMARY: Section 1: Configuration Management / Distribution-Support/ Phenomenology: Since beginning the NPSNET documentation project in January 1995, the following documents have been produced: 1) System Overview, an overview of the system and a variety of reference items (18 pages), 2) User Guide, a complete hands-on guide to running NPSNET and utilizing its many features (32 pages), 3) Programmer's Guide, a description of NPSNET source code and internal operations (64 pages--incomplete), 4) Data File Specification and Interface Guide, a complete account of the input and configuration files used by NPSNET (31 pages), and 5) Configuration and Set-up Guide, a guide to obtaining and installing NPSNET (12 pages). Four of the five books have been completed, reviewed for correctness, and distributed. The documents are available on-line in ASCII, PostScript, and HTML.

Configuration Management: While NPSNET has been a research supported system, the software Configuration Management (CM) has been very informal. Under this project, a formal and viable CM system. This first involved in surveying other developers in the field to determine what system, if any, they are using and what are the benefits and drawbacks of their systems. After surveying approximately fifteen CM systems and users, ClearCase was chosen. While this was in process, the hiring action on a support/ CM person was completed. Once he came inboard, he has stood up the first CMed version of NPSNET (IV.8), which is currently in Beta release. This has involved a considerable amount of testing, debugging, and restructuring. NPSNET-IV.8 will be formally released. This will be the first supported and CM version of NPSNET. During the next reporting period, the graduating students will be integrating their work into NPSNET and a formal Bug Tracking mechanism will be established.

Distribution/Support: NPSNET has been on anonymous FTP for over a year. Under the first installment of this project the service to a World Wide Web (WWW) home page allowing for much easier browsing was upgraded. The distribution page, http:/ /cs.nps.navy.mil/research/npsnet/distribution/page.html, contains the source and libraries and all for the completed documentation. In addition to the WWW page, three mailing lists have been created and staffed to answer questions: npsnet, npsnet-info, and npsnet-tech. Automated registration process via email. Auto response indicates how to download models and terrains. User's email automatically added to official mailing list.

Phenomenology: This work is being done in conjugation with Loral-ADS (Bellevue). During the initial part of this project most of the effort has been on support for LADS. This has entailed the conversions of terrain databases, answering questions with regard to the workings of NPSNET and Performer based systems. A coordination visit has been made to LADS and the first portion of the code has recently been turned over to NPS for integration into the baseline.

Section 2: Terrain Issues: The work in this section has not progressed as far as anticipated in the main direction due to the late contract awarding to CMU.

34

<u>Terrain tools/ Support</u>: The terrain tool developed under the first phase of this project was designed to support two major functions: comparative terrain visualization and the JCS demonstration. The first set of tools takes the ADDWAMS data sets and generates real-time fly though data sets, Multigen Flight. Two or three of these data sets can then be placed side by side and flown though with a single eyepoint. The eyepoint can be a fixed elevation off the ground or free fly. The second set of tools were used at the JCS demonstration to demonstrate SE terrain database construction and trade-offs. The first program was a fly though a section of the Bosnia database as the grid, microterrain, network, culture, and vegetation features were added; the second program was a single eye point fly through of Range 400 at different resolution showing the differences in polygon counts and frame rates.

<u>SEDRIS Work</u>: Several SEDRIS meetings have been attended and presentations made; developed the first working example of a working SEDRIS program and data access. Work is continuing with the SEDRIS group.

<u>Dynamic Terrain Databases</u>: The major effort in the development of dynamic terrain has been the development and modification of the terrain routines in NPSNET-IV.8. This allows rapid model substitution and specification. Preliminary work has been done in support of Terrain paging.

Section 3: Suppor t/Unplanned Work: Files were reorganized into a new directory structure. The goal is to make the code more modular and extensible and to minimize the amount of code to "check out" for student/other modification. NPSNET-IV.8's ability to find textures/models was updated. This greatly enhances the ability to add models/terrains. It also enables easy removal if desired. Compartmentalizing terrain's specific models/textures to avoid mass model collections in one directory eases distribution.

At the October 1995 Association of the United States Army Conference in Washington DC, the Naval Postgraduate School and SARCOS Research Corporation demonstrated the interconnection of two different human mobility platforms with sensored upper bodies, a stick and throttle controlled human figure, and ModSAF based human icons. Of these varied control paradigms, one mobility platform was located remotely in Fort Benning, Georgia, and the rest were at the conference. Communications with the remote entity was done over the Distributed Simulation Internet. Local communications were done via a three tiered hierarchical network scheme, the top two layers using the Distributed Interactive Simulation protocols. The lowest level protocol is device dependent.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Configuration management, system overview, terrain tools

CAPTION-BASED ACCESS TO MULTIMEDIA DATABASES
Neil Rowe, Associate Professor
Amr Zaky, Assistant Professor
Brian Frew and Torrey Loomis, Staff
Department of Computer Science
Sponsor: Advanced Research Projects Agency

OBJECTIVE: To study routine use of natural-language captions to facilitate access to a multimedia database, by providing a smarter filter on candidate data.

SUMMARY: Continued building the MARIE-2 system, focusing this year on (1) natural-language processing of photograph captions, (2) image processing of captioned photographs, and, (3) study of load balancing of retrieval processing among processors. For (1), completed a statistical parser and bootstrapped its statistics from previous results, demonstrating significantly improved performance over MARIE-1. For (2), completed and tested a region-classification program that does region segmentation uses a variety of robust criteria and then applies a neural network. The neural net was trained to classify a region as one of 25 domain categories for regions in test photographs, and then tested it on

other photographs. Performance was significantly better than with a case-based approach to region classification, and improved significantly with training. For (3), studied the problem of load balancing of query processing when multiple processors are available, a quick way to speed processing. Mathematical criteria were developed for when to balance during a series of information filtering activities. These criteria were supported by extensive testing, both with simulations and with the real system.

PUBLICATIONS:

Rowe, N.C. and Laitinen K., "Semiautomatic Disabbreviation of TechnicalText," Information Processing and Management, Vol. 31, 6th Ed., pp. 851-857, 1995.

Rowe, N.C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," Proceedings of AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-Picture Co-Reference," Proceedings of Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

Rowe, N.C., "Universal Mission Planning for Robotic Vehicles," Proceedings of American Nuclear Society 6th Topical Meeting on Robotics and Remote Systems, Monterey CA, February 1995.

CONFERENCE PRESENTATIONS:

Rowe, N. C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Progress on the MARIE Project," Presentation at ARPA I3 (Intelligent Integration of Information) Workshop, Silver Springs, MD, June 1995.

Rowe, N. C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-Picture Co-Reference," Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

Rowe, N.C., "Universal Mission Planning for Robotic Vehicles," American Nuclear Society 6th Topical Meeting on Robotics and Remote Systems, Monterey CA, February 1995.

THESES DIRECTED:

Schiavo, S., "An Intrusion-Detection Tutoring System Using Means-Ends Analysis," Master's Thesis, March 1995.

Roberts, C., "Plan-Based Simulation of Malicious Intruders on a Computer System," Master's Thesis, March 1995.

Koman, B., "Implementing a Periodic Scheduler on a Network of Transputers," Master's Thesis, September 1995.

Tavares, J., "Eureka: A VSM Implementation of Data Merging," Master's Thesis, September 1995.

OTHER:

Poduced the MARIE-2 system as software.

COMPUTER SCIENCE

DOD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interfaces

KEYWORDS: Multimedia, retrieval, captions, filtering, language, pictures, images

INTELLIGENT ACCESS TO A DATABASE OF MILITARY PHOTOGRAPHS

Neil C. Rowe, Associate Professor
Amr Zaky, Assistant Professor
Brian Frew and Torrey Loomis, Staff
Department of Computer Science
Sponsor: Army Artificial Intelligence Center

OBJECTIVE: To study routine use of natural-language captions to facilitate access to a multimedia database, by providing a smarter filter on candidate data.

SUMMARY: Continued building the MARIE-2 system, focusing on (1) natural-language processing of photograph captions, (2) image processing of captioned photographs, and, (3) study of load balancing of retrieval processing among processors. For (1), completed a statistical parser and bootstrapped its statistics from previous results, demonstrating significantly improved performance over MARIE-1. For (2), completed and tested a region-classification program that does region segmentation uses a variety of robust criteria and then applies a neural network. The neural net was trained to classify a region as one of 25 domain categories for regions in test photographs, and then tested it on other photographs. Performance was significantly better than with a case-based approach to region classification, and improved significantly with training. For (3), studied the problem of load balancing of query processing when multiple processors are available, a quick way to speed processing. Mathematical criteria were developed for when to balance during a series of information filtering activities. These criteria were supported by extensive testing, both with simulations and with the real system.

PUBLICATIONS:

Rowe, N.C. and Laitinen, K., "Semiautomatic Disabbreviation of Technical Text," Information Processing and Management, Vol. 31, 6th Ed., pp. 851-857, 1995.

Rowe, N.C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," Proceedings of AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-Picture Co-Reference," Proceedings of Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

Rowe, N.C., "Universal Mission Planning for Robotic Vehicles," Proceedings of American Nuclear Society 6th Topical Meeting on Robotics and Remote Systems, Monterey CA, February 1995.

CONFERENCE PRESENTATIONS:

Rowe, N.C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Progress on the MARIE Project," Presentation at ARPA I3 (Intelligent Integration of Information) Workshop, Silver Springs, MD, June 1995.

Rowe, N.C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-Picture Co-Reference," Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

Rowe, N.C., "Universal Mission Planning for Robotic Vehicles," American Nuclear Society 6th Topical Meeting on Robotics and Remote Systems, Monterey CA, February 1995.

THESES DIRECTED:

Schiavo, S., "An Intrusion-Detection Tutoring System Using Means-Ends Analysis," Master's Thesis, March 1995.

Roberts, C., "Plan-Based Simulation of Malicious Intruders on a Computer System," Master's Thesis, March 1995.

Schiavo, S., "An Intrusion-Detection Tutoring System Using Means-Ends Analysis," Master's Thesis, March 1995.

Roberts, C., "Plan-Based Simulation of Malicious Intruders on a Computer System," Master's Thesis, March 1995.

Koman, B., "Implementing a Periodic Scheduler on a Network of Transputers," Master's Thesis, September 1995.

Tavares, T., "Eureka: A VSM Implementation of Data Merging," Master's Thesis, September 1995.

OTHER:

Produced the MARIE-2 system as software.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interfaces

KEYWORDS: Multimedia, retrieval, captions, filtering, language, pictures, images

STATISTICAL PARSING OF MULTIMEDIA CAPTIONS
Neil C. Rowe, Associate Professor
Amr Zaky, Assistant Professor
Brian Frew and Torrey Loomis, Staff
Sponsor: Naval Postgraduate School

OBJECTIVE: To study routine use of natural-language captions to facilitate access to a multimedia database, by providing a smarter filter on candidate data.

SUMMARY: Continued building the MARIE-2 system, focussing on natural-language processing of photograph captions; completed a statistical parser and bootstrapped its statistics from previous results, demonstrating significantly improved performance over MARIE-1.

PUBLICATIONS:

Rowe, N.C. and Laitinen, K., "Semiautomatic Disabbreviation of Technical Text," Information Processing and Management, Vol. 31, 6th Ed., pp. 851-857, 1995.

Rowe, N.C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," Proceedings of AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-Picture Co-Reference," Proceedings of Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

Rowe, N.C., "Universal Mission Planning for Robotic Vehicles," Proceedings of American Nuclear Society 6th Topical Meeting on Robotics and Remote Systems, Monterey, CA, February 1995.

CONFERENCE PRESENTATIONS:

Rowe, N.C., "Redundant Processing as a Solution to the Mismatch Between Natural Language and Vision," AAAI Fall Symposium on Computational Models for Integrating Natural Language and Vision, Cambridge, MA, November 1995.

Rowe, N.C., "Progress on the MARIE Project," Presentation at ARPA I3 (Intelligent Integration of Information) Workshop, Silver Springs, MD, June 1995.

Rowe, N.C., "Retrieving Captioned Pictures Using Statistical Correlations and a Theory of Caption-picture Co-Reference," Fourth Annual Symposium on Document Analysis and Retrieval, Las Vegas, NV, April 1995.

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Tavares, J., "Eureka: A VSM Implementation of Data Merging," Master's Thesis, September 1995.

OTHER:

Produced the MARIE-2 system as software.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interfaces

KEYWORDS: Multimedia, retrieval, captions, filtering, language, pictures, images

SAFETY ANALYSIS OF THE MESA MISSILE TEST FACULTY
Timothy Shimeall, Associate Professor
Department of Computer Science
Sponsor: Unfunded

OBJECTIVE: Demonstration of the effectiveness of software tools to perform safety analysis in the context of a real Navy software development project.

SUMMARY: During 1995, Professor Shimeall and his students employed a variety of NPS-developed tools to the analysis of the safety of the control software in the NAWC's new Missile Encounter Simulation Areana (MESA). This analysis established that the system design and implementation prevented an important class of hazards. This research

also established the utility of the NPS-developed tools in actual project conditions and suggested further directions for the development of safety analysis tools.

PUBLICATIONS:

Shimeall, T. J. and Winter, M. W., "Analysis of Safety-Critical Control Software for a Missile Test Facility," Energy Week '96, Houston, TX, 30 January - 2 February 1996.

Reid, W.S. and Shimeall, T. J., "Automated Code Translation Tool for Software Fault Tree Analysis," ISSAT Second International Conference on Reliability and Quality in Design, March 1995.

THESES DIRECTED:

Mason, R.W., "Fault Isolator Tool for Software Fault Tree Analysis," Master's Thesis, March 1995.

Winter, M.W., "Software Fault Analsysis of an Automated Control System Device Written in Ada," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Safety, testing, software

GEOLOCATION WORKBENCH
Timothy Shimeall, Associate Professor
Department of Computer Science
Herschel Loomis, Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: Develop an environment for comparison and development of geolocation algorithms.

SUMMARY: During 1995, Professors Shimeall and Loomis, with their students, laid the initial development foundations for the Geolocation Workbench, a software environment for the design and analysis of algorithms for Geolocation. Professor Shimeall provided the software development expertise to guide the requirements development and software prototyping for the interface of the environment.

THESES DIRECTED:

Humphries, T.E., "Geolocation Workbench System," Master's Thesis, September 1995.

Campbell, R.E., "Geolocation Workbench," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Signal processing, sensors, run-time analysis

COMPUTER SCIENCE

ON-LINE POLYMORPHIC TYPE INFERENCE IN IMPERATIVE LANGUAGES
Dennis Volpano, Assistant Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: This is an ongoing project whose objective is to investigate new type theories for traditional imperative programming languages.

SUMMARY: A polymorphic type system was designed for a core, block-structured imperative programming language with variables and pointers. The type system and its soundness proof gave new insight into proving the original Edinburgh LCF ML type system sound. LCF ML has variables, but no pointers. Soundness of the LCF ML type system has remained open since the mid seventies. The LCF ML type system was proven sound. A polymorphic type system was designed for Kernighan and Ritchie C and proved sound.

PUBLICATION:

Pederson, C., "Uniform Representation of Data Types in Polymorphic C," Naval Postgraduate School Technical Report, NPS-CS-95-004, October 1995

CONFERENCE PRESENTATIONS:

Volpano, D., "Polymorphic Typing of Variables and References," IFIP WG2.8 Meeting, Santa Cruz, CA, January 1995.

Volpano, D. and Smith, G., "Polymorphic Variables," Newton, Themes in the Semantics of Computation, Cambridge UK, July 1995.

THESIS DIRECTED:

Bonem, P., "Implementing Polymorphism in Polymorphic C," Master's Thesis, September 1995.

OTHER:

Smith, G. and Volpano, D., "Polymorphic Typing of Variables and References," submitted to ACM TOPLAS, September 1995.

Smith, G. and Volpano, D., "Towards an ML-style Polymorphic System for C," to appear, European Symposium on Programming, Linkoping Sweden, April 1996.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Programming languages, semantics, static analyses

COMPUTER SCIENCE

VERIFICATION OF HIGH-SPEED NETWORK PROTOCOLS
Dennis Volpano, Assistant Professor
G.M. Lundy, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This was a one-year project aimed at the formal verification of high-speed data transport protocols.

SUMMARY: The SNR protocol was selected as a high-speed transport protocol for formal verification due to its complexity and suitability for fiber-optic data transmission. Two verification tools were considered, namely SMV, the symbolic model checker from Carnegie Mellon University, and Murphi, a tool for the formal verification of asynchronous concurrent systems developed at Stanford. Murphi was chosen because it was easier to express those formal properties we wished to verify. Developing the appropriate properties was a significant part of the project. SNR has multiple phases, each of which may be run in one of four modes. The first phase is the connection establishment phase, which was completely verified using Murphi. However Murphi was less suitable for verifying the subsequent phases. The key property of interest for the other phases is self stabilization, which guarantees the protocol will eventually reach a safe state from any unsafe state. This is the centerpiece of SNR and it must be verified. However, time did not permit it.

THESES DIRECTED:

Pederson, C., "Application of a Mechanical Verification System to a Communication Protocol," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Command, Control and Communications (C3)

KEYWORDS: Asynchronous systems, verification, protocols

NPSNET RESEARCH GROUP
Michael J. Zyda, Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The NPSNET Research Group is a group of faculty, staff, and students at the Naval Postgraduate School, Monterey, California that works in all areas of networked virtual environments. Professor Michael Zyda and Assistant Professor David Pratt are the principal investigators of this research group and determine its long term and short term objectives. Students involved with the research group are MS and PhD candidates of the Department of Computer Science at the Naval Postgraduate School.

SUMMARY: The NPSNET Research Group is a group of faculty, staff, and students at the Naval Postgraduate School, Monterey, California that works in all areas of networked virtual environments. Professor Michael Zyda and Assistant Professor David Pratt are the principal investigators of this research group and determine its long term and short term objectives. Students involved with the research group are MS and PhD candidates of the Department of Computer Science at the Naval Postgraduate School.

The research group is currently focused on the following virtual environment (VE) research topics: the large-scale networking of virtual environments (environments greater than 1,000 players), VE network applications protocols, rapidly reconfigurable VE network protocols, Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) protocols, the real-time walkthrough of large-scale networked Ves, world modeling software for managing large scale networked VEs, the instrumentation of the human body and its representation in the networked VE, hypermedia

integration - how we place video, audio, imagery and textual data in the networked VE, and geometric modeling - terrain, building and other object modeling.

The NPSNET Research Group's efforts focus on the development of the above software areas and the integration of proven components of that work into our core software system, NPSNET. NPSNET is currently capable of simulating articulated humans, and ground, air and sea-going vessels in the DIS networked virtual environment. NPSNET can support about 250-300 players using currently available networking and workstation technology. NPSNET is the first 3D virtual environment that is capable of playing across the multicast backbone (MBONE) of the Internet.

Our research efforts are funded by a large number of US government funding agencies, including the Advanced Research Projects Agency (ARPA), the US Army Research Laboratories (ARL), the Defense Modeling and Simulation Office (DMSO), US Army TRADOC Analysis Center (TRAC), US Army Topographic Engineering Center (TEC), the Office of Naval Research (ONR) and the Research, Development, Test, and Engineering Division (NRaD) of the Naval Command, Control and Ocean Surveillance Center.

PUBLICATIONS:

Macedonia, M.R., Zyda, M.J., Pratt, D.R., Brutzman, D.P., and Barham, P.T., "Exploiting Reality with Multicast Groups," IEEE Computer Graphics & Applications (revised from apearance in the VRAIS '95 Proceedings), pp. 38-45, September 1995.

Zyda, M.J., "Virtual Reality: Scientific and Technological Challenges," (Editors: Nathaniel I. Durlach and Anne S. Mavor, Committee on Virtual Reality Research and Development, National Research Council), Sections written or with major contributions: Chapters - "Executive Summary," "Overview," "Computer Hardware and Software for the Generation of Virtual Environments," and "Networking and Communications," National Academy of Sciences Press, Washington, D.C., 1995.

Bible, S.R., Brutzman, D., and Zyda, M., "Using Spread Spectrum Ranging Techniques for Position Tracking in a Virtual Environment," Proceedings of Network Realities '95, Boston, MA, 26 - 28 October 1995.

Macedonia, M. and Zyda, M., "A Taxonomy for Networked Virtual Environments," Proceedings of Network Realities '95, Boston, MA, 26-28 October 1995.

Zyda, M., Pratt, D.R., Pratt, S., Barham, P., and Falby, J.S. "NPSNET-HUMAN: Inserting The Human Into The Networked Synthetic Environment," Proceedings of the 13th DIS Workshop, pp. 103-106, Orlando, FL, 18-22 September 1995.

Lentz, F.C., Shaffer, A.B., Pratt, D.R., Falby, J.S., and Zyda, M., "NPSNET: Naval Training Integration," Proceedings of the 13th DIS Workshop, pp. 107-112, Orlando, FL, 18-22 September 1995.

Waldroup, M.S., Pratt, S.M., Pratt, D.R., McGhee, R.B., Falby, J.S., and Zyda, M.J., "Real-Time Upper Body Articulation of Humans in a Networked Virtual Environment," Proceedings of the First ACM Workshop on Simulation and Interaction in Virtual Environments, University of Iowa, pp. 210-214, 13-15 July 1995.

Brutzman, D.P., Macedonia, M.R., and Zyda, M.J.,"Internetwork Infrastructure Requirements for Virtual Environments," Proceedings of the NII 2000 Forum of the Computer Science and Telecommunications Board, National Research Council. Also accepted for publication in the Proceedings of the 1995 Symposium on VRML, Washington, D C, 23-24 May 1995.

Macedonia, M.R., Brutzman, D.P., Zyda, M.J., Pratt, D.R., Barham, P.T., Falby, J., and Locke, J., "NPSNET: A Multi-Player 3D Virtual Environment Over the Internet," Proceedings of the 1995 Symposium on Interactive 3D Graphics, Monterey, CA, 9-12 April 1995.

Macedonia, M. R., Zyda, M.J., Pratt, D.R., Brutzman, D.P., and Barham, P.T., "Exploiting Reality with Multicast Groups: A Network Architecture for Large Scale Virtual Environments," Proceedings of the 1995 IEEE Virtual Reality Annual Symposium, pp. 2-10, Research Triangle Park, Raleigh, NC, 11-15 March 1995.

Zyda, M., "Networked Virtual Environments," Proceedings of the 1995 IEEE Virtual Reality Annual Symposium, pp. 230-231, Research Triangle Park, Raleigh, NC, 11-15 March 1995.

Lentz, F.C., Shaffer, A.B., Pratt, D.R., Falby, J.S., and Zyda, M.J., "Virtual Reality: Naval Training for the Future," accepted as a Professional Note for the Naval Institute Proceedings, 1995.

Pratt, D.R., Zyda, M., and Kelleher, K., "Virtual Reality: In the Mind of the Beholder," IEEE Computer, (editors notes for the special issue on virtual environments), pp. 17-19, July 1995.

Macedonia, M.R., Zyda, M. J., Pratt, D.R., Brutzman, D.P., and Barham, P.T. "Building Large-Scale Virtual Environments: A Network Software Architecture," Proceedings of Industrial Virtual Reality '95, pp. 18-28, Tokyo, Japan (as invited speaker), 28 - 30 June 1995.

CONFERENCE PRESENTATIONS:

Zyda, M.J., "NPSNET Research Group Dismounted Infantry VR Demo at AUSA '95," Association for the United States Army Conference, Washington, D.C., 16-18 October 1995.

Macedonia, M.R., Brutzman, D.P., Zyda, M.J., Pratt, D.R., Barham, P.T., Falby, J., and Locke, J., "NPSNET: A Multi-Player 3D Virtual Environment Over the Internet," Video Proceedings of the 1995 Symposium on Interactive 3D Graphics, Monterey, CA, 9 - 12 April 1995.

Zyda, M.J., "National Research Council Report: Virtual Reality - Scientific and Technological Challenges" and "Networking Large Scale Virtual Environments," invited speaker to the Second International Conference on the Military Applications of Synthetic Environments and Virtual Reality (MASEVR '95), Stockholm, Sweden, 6-8 December 1995; invited speaker to the STC Consortium at Brown University. The talk was transmitted to UNC - Chapel Hill, the University of Utah, Caltech, Cornell University and Georgia Tech, 16-17 November 1995.

Zyda, M.J., "Using Spread Spectrum Ranging Techniques for Position Tracking in a Virtual Environment" and "A Taxonomy for Networked Virtual Environments," Network Realities '95 Conference, Boston, MA, 26-28 October 1995.

Zyda, M.J., "National Research Council Report: Virtual Reality - Scientific and Technological Challenges," Carnegie Mellon University Colloquium series on Human Computer Interaction, 25 October 1995.

Zyda, M. J., "NPSNET-HUMAN: Inserting The Human Into The Networked Synthetic Environment," and "NPSNET: Naval Training Integration," 13th Workshop on Standards for the Interoperability of Distributed Simulations, Orlando, FL, 18-21 September 1995.

Zyda, M.J., "Networking Virtual Environments," National Research Council CSTB Workshop on HPCC - Research and Applications, National Academy of Sciences, 24 August 1995.

Zyda, M.J., "Computer Hardware, Software and Networking for the Generation of Virtual Environments," panel on virtual reality at the American Psychological Association annual meeting, New York City, NY, 13 August 1995.

Zyda, M.J., "Computer Hardware, Software and Networking for the Generation of Virtual Environments," SIGGRAPH '95 panel entitled "Virtual Reality Funding Priorities and Research Agenda: Report by the National Research Council Committee on VR R&D", 6-11 August 1995.

Zyda, M.J., "Building Large-Scale Virtual Environments: A Network Software Architecture," Industrial Virtual Reality '95, Tokyo, Japan (as invited speaker), 28-30 June 1995.

Zyda, M.J., "NPSNET: A Multi-Player 3D Virtual Environment Over the Internet," 1995 Symposium on Interactive 3D Graphics, Monterey, CA, 9-12 April 1995.

Zyda, M. J., "Networking Large-Scale Virtual Environments," VRAIS '95 Panel on Networked Virtual Environments, 11-15 March 1995.

OTHER:

Received Recognition of Service Award, April 1995, from the Association for Computing Machinery for role as Symposium Chair of the 1995 Symposium on Interactive 3D Graphics.

Dec. 95: Appointed as Member of the Technical Advisory Board of the Center for Research in Computer Graphics, Providence, Rhode Island.

Aug 95: Member of the ARPA Technical Advisory Board for the Simulation Based Design project.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual environment, VE network, Distributed Interactive Simulation (DIS)

1995

Faculty Publications
and
Presentations

COMPUTER SCIENCE

JOURNAL PAPERS

Irvine, C., "Report on Tenth Annual Computer Security Applications Conference," Electronic Cipher #3, IEEE Computer Society TC on Security and Privacy, 13 January 1995. (http://www.itd.nrl.navy. mil/ITD/5540/ieee/cipher/cipher-archive.html)

Irvine, C., "Report on the Defensive Information Warfare Symposium," Electronic Cipher #3, IEEE Computer Society TC on Security and Privacy, 23 December 1995. (http://www.itd.nrl. navy.mil/ITD/5540/ieee/cipher/)

Lewis, T., "Where is Client/Server Computing Headed?," IEEE COMPUTER, Vol. 28, No. 4, pp. 49-55, April 1995.

Luqi, Shing, M., and Berzins, V., "An Automated Prototyping Tool for System Development and Acquisition," NetFocus, No. 211, pp. 2-3, May 1995.

Luqi and Cooke, D., "How to Combine Nonmonotonic Logic and Rapid Prototyping to Help Maintain Software," International Journal of Software Engineering and Knowledge Engineering, Vol. 5, Number 1, pp. 89-118, March 1995.

Macedonia, M.R., Zyda, M.J., Pratt, D.R., Brutzman, D.P., and Barham, P.T., "Exploiting Reality with Multicast Groups," IEEE Computer Graphics & Applications, pp. 38-45, September 1995.

McMillan, S., Orin, D.E., and McGhee, R.B., "Efficient Dynamic Simulation of an Underwater Vehicle with a Robotic Manipulator," IEEE Trans. on Systems, Man, and Cybernetics, Vol. 25, No. 8, pp. 1194-1206, August, 1995.

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